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Development of a Course of Action Simulation Capability

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ABSTRACT

This document provides a report for the Australian Defence Simulation Office (ADSO) on COA-Sim R&D undertaken with the support of ADSO minors funds in the 03/04 financial year. The R&D focussed on developing a prototype Course of Action Simulation capability. Course Of Action Simulation (COA-Sim) is an R&D program aimed at exploring the applicability of simulation to operations planning support. COA-Sim aims to provide a systematic component to the COA development and analysis phases of operations planning. This will result in an increased confidence in the COA and a better knowledge of unexpected possible outcomes, resulting in a more refined and well-founded plan. An exploration of the use and applicability of simulation in support of planning has been undertaken with the concepts being successfully demonstrated in a prototype COA-Sim environment.

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Executive Summary

The ability of modelling and simulation (M&S) to assist and support planners in the development and analysis of operations plans is a current requirement of the Australian Defence Organisation (ADO). Command and Control Division of the Defence Science and Technology Organisation (DSTO) has an R&D program aimed at developing an M&S suite to support Australian Defence Force (ADF) operational-level planning.

Course Of Action Simulation (COA-Sim) is an R&D program aimed at exploring the applicability of simulation to operations planning support. Within the COA-Sim environment military operations planners incrementally develop, refine and analyse a course of action. COA-Sim provides an integrated, consistent and coherent approach for exploring the feasibility, effectiveness and risk of a COA using simulations containing explicit behavioural representations in space and over time for own and opposing forces. Planners will therefore be able to make better decisions regarding the COA by having a better knowledge of possible outcomes and potential risks.

COA-Sim is a collaborative program between DSTO C2D and the Australian Defence Force Warfare Centre (ADFWC) Simulation Section. The ADFWC supports the operational level of command through simulation-based training and exercises. Components of COA-Sim are of immediate benefit to the existing ADFWC training capability by making it more efficient and effective. This collaboration strengthens user confidence in the simulation and provides a solid foundation for its transition to the operations planning community. Benefits to concept development and experimentation also exist.

This document provides a report for the Australian Defence Simulation Office (ADSO) on COA-Sim R&D undertaken with the support of ADSO Minors funding in the 03/04 financial year. This R&D focussed on developing a prototype Course of Action Simulation capability.

In addition to the ADSO Minors funding two DSTO tasks also support the COA-Sim R&D program, namely the ADFWC-sponsored task JNT02/196 "M&S Support to ADFWC" and the DJFHQ task JNT02/198 "M&S - DJFHQ Operations Planning". These tasks provide the resources to lead, manage and undertake the underlying scientific research in support of the COA-Sim program.

An exploration of the use and applicability of simulation in support of planning has been undertaken with the concepts being successfully developed and demonstrated in

a prototype COA-Sim environment. Significant progress has been made on developing a number of tools within the environment and a brief summary is provided in the following paragraphs.

The COA-Sim environment contains a number of technical components, including a graphical user interface, a suite of sophisticated intelligent software agents that enable automation and behavioural representation within the simulation environment, and an underlying constructive simulation representing the physical assets. There are two constructive simulations available within the COA-Sim environment, the Joint Theatre Level Simulation (JTLS) and the Joint Semi Automated Forces (JSAF).

There are two key functional components of the COA-Sim environment: planning support tools (for planners or planners' assistants); and order & behaviour support tools (for simulation operators). A number of these tools have been developed and are available within a prototype COA-Sim environment.

A planning options tool is available where a planner would specify a goal condition (or military end state) and the tool would suggest broad options using built-in generic information about military capabilities. A selection of operational-level orders (combat air patrol (CAP), strike, and air reconnaissance) have been integrated into JTLS to provide order and behaviour support to the JTLS operator. A JTLS-based order and behaviour tool allows the user to easily see the hierarchical contents of each operational-level task, the detailed field values of a sub-task, and also quickly see the automation status and the simulation status of the order. A CAP operational-level order has been integrated into JSAF to provide order and behaviour support to the JSAF operator - the same functionality that is available in JTLS. A simple JSAF-based analysis tool has also been developed to analyse and display military capabilities of a force. The current implementation of this tool undertakes analysis that characterises the military capabilities of a force in terms of its ability to attack.

Further funding would allow R&D into the extension and integration of the standalone tools to provide unified planning options, feasibility assessment and analysis modes within the COA-Sim environment.

Contents

Abbreviations

ADF	Australian Defence Force
ADFWC	ADF Warfare Centre
ADO	Australian Defence Organisation
ADSO	Australian Defence Simulation Office
AEW	Airborne Early Warning
ALOC	Air Lines of Communication
BDA	Battle Damage Assessment
C2	Command and Control
C2D	Command and Control Division
CAP	Combat Air Patrol
CD&E	Concept Development and Experimentation
COA	Courses of Action
COA-Sim	Course of Action Simulation
DJFHQ	Deployable Joint Force Head Quarters
DSTO	Defence Science and Technology Organisation
GIAC	Graphical Input Aggregate Control
GUI	Graphical User Interface
HLA	High Level Architecture
JIPB	Joint Intelligence Preparation of the Battlefield
JMAP	Joint Military Appreciation Process
JSAF	Joint Semi-Automated Forces
JTLS	Joint Theatre Level Simulation
M&S	Modelling and Simulation
MEZ	Maritime Exclusion Zone
NORCOM	Northern Command
OPAREA	Operational Area
OPFOR	Opposing Force
R&D	Research and Development
SEAD	Suppression of Enemy Air Defence
SOP	Standing Operating Procedures
VV&A	Verification, Validation and Accreditation

1. Introduction

The ability of modelling and simulation (M&S) to assist and support planners in the development and analysis of operations plans is a current requirement of the Australian Defence Organisation (ADO) [1]. Command and Control Division (C2D) of the Defence Science and Technology Organisation (DSTO) has an R&D program aimed at developing a M&S suite to support Australian Defence Force (ADF) operational-level planning.

Course Of Action Simulation (COA-Sim) is an R&D program aimed at exploring the applicability of simulation to operations planning support. Within the COA-Sim environment military operations planners incrementally develop, refine and analyse a course of action. COA-Sim provides an integrated, consistent and coherent approach for exploring the feasibility, effectiveness and risk of a COA using simulations containing explicit behavioural representations in space and over time for own and opposing forces. Planners will therefore be able to make better decisions regarding the COA by having a better knowledge of possible outcomes and potential risks.

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This document provides a report for the Australian Defence Simulation Office (ADSO) on COA-Sim R&D undertaken with the support of ADSO minors funds in the 03/04 financial year, R&D which focussed on developing a prototype Course of Action Simulation capability. A summary of the milestones delivered is provided in Section 2. Detail on the specifics of the capability and possible follow on activities is provided in Sections 3-7.

In addition to the ADSO Minors funding two DSTO tasks also support the COA-Sim R&D program, namely the ADFWC-sponsored task JNT02/196 "M&S Support to ADFWC" and the DJFHQ task JNT02/198 "M&S - DJFHQ Operations Planning". These tasks provide the resources to lead, manage and undertake the underlying scientific research in support of the COA-Sim program.

2. A Prototype COA-Sim Capability: Summary

2.1 Milestones

The development schedule for the prototype COA-Sim capability is shown in Table 1.

Table 1. Prototype COA-Sim capability development schedule.

Development of a Course of Action Simulation Capability		
Milestone	Date	**Deliverable**
	31st Dec 2003	Development of intelligent software agents and a graphical user interface (GUI) in support of a simple Course of Action simulation capability. An existing constructive simulation will be used, namely JTLS.
1		A "planning options agent" that finds a set of alternative plans to achieve a given military end-state
2		an "order and behaviour agent" that translates operational-level tasks into simulation-level behaviours (eg CAP, strike, air surveillance) in JTLS
3		a "task decomposition GUI" that will display operational-level tasks and the decomposition to sub-tasks as provided by the "order and behaviour agent"
4		a "simulation status GUI" that will display simulation status as provided by the "order and behaviour agent"
5		the ability to select varying levels of automation from fully automatic through to full user confirmation
	30th April 2004	Delivery of a prototype Course of Action simulation capability with a graphical user interface, a selection of intelligent software agents, and a constructive simulation. Intelligent agent functionality and GUI features will extend development as stated in the December 03 milestones (No 1-5) and will include a **selection** of the following milestones (No 6-13). Integration of the JSAF constructive simulation into the COA-Sim environment will also be undertaken.
6		further development of the "planning options agent" to accommodate for more tasks and end-states

		Development of a Course of Action Simulation Capability (cont.)
Milestone	Date	**Deliverable**
7		further development of the "order and behaviour agent" to accommodate the JSAF simulation
8		development of a "task feasibility assessment agent" to determine the feasibility of undertaking a certain task with the specified resources and / or determining resources required to undertake a certain task
9		a "simulation results agent" that provides operational-level reports of simulation outcomes
10		extending the "task decomposition GUI" to include timing and resourcing information
11		a "planning options GUI" to display planning options as provided by the "planning options agent"
12		a "simulation results GUI" to display results from the "simulation results agent"
13		the ability to manipulate the tasks in the "task decomposition GUI" and "planning options GUI"
14	30th April 2004	Delivery of a **report** outlining the outcomes of the "Course of Action Simulation Capability" Project, providing recommendations for the way forward, and providing recommendations of significance to JP2079.

The milestones for the first six months concerned development of intelligent software agents and a graphical user interface (GUI) in support of a simple COA-Sim capability (containing the JTLS constructive simulation). All five milestones (numbers 1-5) were achieved.

- Milestone 1. A "planning options agent" that finds a set of alternative plans to achieve a given military end-state.
  This milestone has been achieved and is described in detail in Section 4.2.1.
- Milestone 2. An "order and behaviour agent" that translates operational-level tasks into simulation-level behaviours (eg combat air patrol (CAP), strike, air surveillance) in JTLS.
  This milestone has been achieved and is described in detail in Section 4.3.1 (see Figures 4, 5 & 6).
- Milestone 3. A "task decomposition GUI" that will display operational-level tasks and the decomposition to sub-tasks as provided by the "order and behaviour agent".
  This milestone has been achieved and is described in detail in Section 4.3.1 (see Figure 7).
- Milestone 4. A "simulation status GUI" that will display simulation status as provided by the "order and behaviour agent".

This milestone has been achieved and is described in detail in Section 4.3.1 (see Figure 7).

- Milestone 5. The ability to select varying levels of automation from fully automatic through to full user confirmation.
  This milestone has been achieved and is described in detail in Section 4.3.1 (see Figure 7).

The milestones for the last six months concerned delivery of a prototype COA-Sim capability with a graphical user interface, a selection of intelligent software agents, and the JTLS and JSAF constructive simulations. Eight additional milestones (Numbers 6-13) were provided in the original proposal with the statement that "a **selection**" would be undertaken. It was never intended or anticipated that all these milestones could be completed given the proposed resources but this wider selection of milestones provided an opportunity to focus development depending on priority throughout the year (the most significant change in priority related to the introduction of the JSAF constructive simulation). Milestones 7, 9, 11, and 12 were achieved.

- Milestone 7. Further development of the "order and behaviour agent" to accommodate the JSAF simulation.
  This milestone has been achieved and is described in detail in Section 4.4.1 (see Figure 8).
- Milestone 9. A "simulation results agent" that provides operational-level reports of simulation outcomes.
  This milestone has been achieved and is described in detail in Section 4.4.2.
- Milestone 11. A "planning options GUI" to display planning options as provided by the "planning options agent".
  This milestone has been achieved and is described in detail in Section 4.2.1 (see Figure 3).
- Milestone 12. A "simulation results GUI" to display results from the "simulation results agent".
  This milestone has been achieved and is described in detail in Section 4.4.2 (see Figures 9&10).

Milestones 6, 8, 10, and 13 were not achieved, namely

- Milestone 6. Further development of the "planning options agent" to accommodate for more tasks and end-states.
- Milestone 8. Development of a "task feasibility assessment agent" to determine the feasibility of undertaking a certain task with the specified resources and / or determining resources required to undertake a certain task.
- Milestone 10. Extending the "task decomposition GUI" to include timing and resourcing information.
- Milestone 13. The ability to manipulate the tasks in the "task decomposition GUI" and "planning options GUI".

It is hoped that these milestones can be achieved via future ADSO minors funding and/or an ongoing COA-Sim R&D program.

2.2 Financial Expenditure

All of the minors funds made available to this project were spent on technical support services, specifically via extension of an existing contract with KAZ Technology

(formerly Aspect Computing) who provides software engineers on a time and materials basis. This arrangement worked well because the contractors were familiar with the existing R&D program and payment on a time and materials basis provided flexibility in determining which milestones were actually achieved (this is considered necessary in a research environment and proved necessary given the recent adoption of JSAF over JTLS).

2.3 Outcomes

COA-Sim aims to provide a systematic component to the COA development and analysis phases of operations planning. This will result in an increased confidence in the COA and a better knowledge of unexpected possible outcomes, resulting in a more refined and well-founded plan.

An exploration of the use and applicability of simulation in support of planning has been undertaken with the concepts being successfully developed and demonstrated in a prototype COA-Sim environment. These tools will assist planners in the construction, modification and analysis of a course of action described by a set of operational-level tasks. The tools are also of immediate benefit to the existing ADFWC simulation-based training capability by making it more efficient and effective.

Further funding would allow R&D into the extension and integration of the standalone tools to provide unified planning options, feasibility assessment and analysis modes within the COA-Sim environment.

3. Course of Action Simulation (COA-Sim)

The key objective of COA-Sim is to explore the applicability of simulation to operations planning support [2]. The COA-Sim R&D program involves:

- Defining the role of COA-Sim within operations planning.
- Developing concepts for and defining requirements on a simulation capability in support of operations planning.
- Developing and demonstrating a prototype COA-Sim capability.
- Identifying the issues facing simulation support to operations planning.
- Identifying COA-Sim concepts relevant to training and exercises, and futures experimentation (capability development).
- Informing the broader ADO simulation community.

3.1 COA-Sim Role

COA-Sim aims to provide simulation support to operations planning. The Joint Military Appreciation Process (JMAP) [3] is the doctrinal Australian joint operations planning process. The JMAP consists of four consecutive steps with a continuous process, the joint intelligence preparation of the battlespace (JIPB), occurring

concurrently with all of the four steps and providing continuous feedback to maintain situation awareness (see Figure 1).

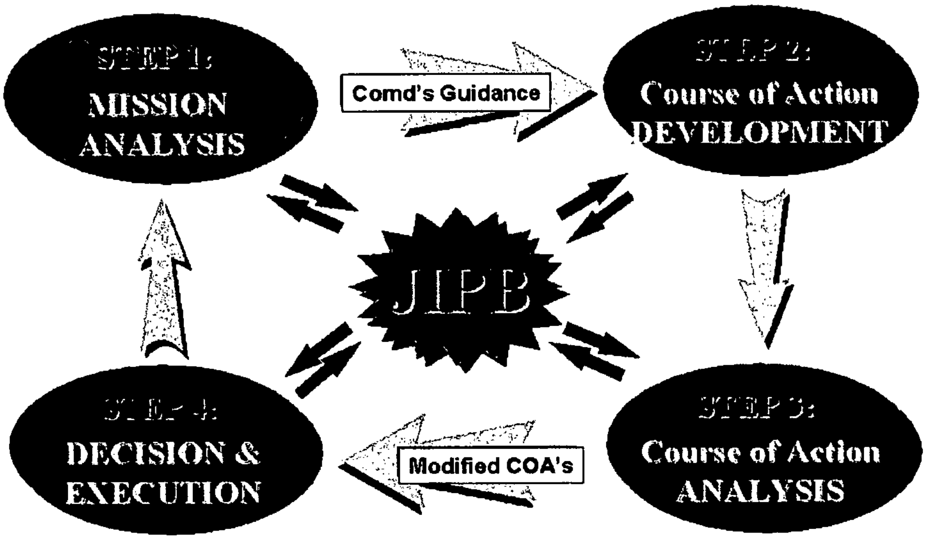

Figure 1. The JMAP.

Step One, Mission Analysis, is the process by which commanders and staff analyse the superior commander's intent in order to determine the objectives that need to be achieved to reach the desired end-state. Step Two, COA Development, involves identifying a range of COA that will best achieve the commander's intent. Step Three, COA Analysis, involves war-gaming each friendly COA in an attempt to predict what may happen during the execution of a COA. This war-gaming phase can take the form of a mental simulation of the COA or a more formal gaming process, not necessarily computer-based. The wargaming should be a process of COA refinement and, if time permits, should be followed by a full execution of the COA, leading to full COA analysis. The results from Step Three enable the commander to determine the probability of success and risks associated with each COA. In Step Four, Decision and Execution, the commander decides which COA should be developed into a plan and executed.

COA-Sim is intended to primarily support Steps 2 and 3 of the JMAP, namely COA development through to analysis.

3.2 COA-Sim Concept

COA-Sim could support COA development (step 2 of the JMAP) in a number of ways. Firstly, a series of broad planning options to achieve a specified military end-state could be provided in the form of a series of operational level tasks. For any planning option a schedule of sub-tasks could be provided. Appropriate resourcing for the tasks could also be advised or a task- or logistics-feasibility assessment could be undertaken.

This would be achieved during the JMAP by a small team of planners' assistants implementing blue planning options, as described by the planners, in the COA-Sim environment. This results in a skeletal COA populated within COA-Sim. This resultant simulation representation could be taken as JMAP 'planning product' into the COA analysis phase. Similarly COA-Sim could be used to assist development of a Red COA.

During the COA analysis phase (Step 3) of the JMAP COA-Sim could be used to analyse (wargame) all or parts of the proposed COA and provide feedback to the planners on potential outcomes, effectiveness and risk, to determine decision points, or highlight unexpected possible outcomes and failure modes that might arise when the COA is executed in time and space with an opposing force (OPFOR). COA-Sim would bring a systematic component to wargaming by simulating the motion of assets and allowing for back-tracking, or fast-forwarding, over time and space. Wargame adjudication would be supported by using COA-Sim to assess the outcomes of engagements and exploring task synchronisation issues.

Either open or closed wargaming could be supported by COA-Sim. This would be achieved during the JMAP by a small team of planners' assistants implementing red and blue actions and counteractions in the COA-Sim environment based on the dynamic interactions of the wargamers. This resultant simulation representation could be taken as JMAP 'planning product' into the decision and execution phase (Step 4) of the JMAP.

In summary COA-Sim could enable
- Exploration of planning options including sub-task scheduling and resourcing;
- Exploration of the feasibility, effectiveness and risk of a single task through to an entire COA;
- Exploration of logistics feasibility;
- Exploration of task synchronisation issues;
- Determination of decision points;
- Wargame adjudication – by providing representative outcomes; and
- Computer tracking of a COA (the motion of assets over time and space), which allows for back-tracking or fast-forwarding.

Most importantly, though, the aim of simulating a COA is to find unexpected possible outcomes and failure modes.

One of the requirements on the COA-Sim environment is to ensure an efficient and effective interface with the operations planning environment. As has already been highlighted it is anticipated that military planners would use COA-Sim with the aid of planners' assistants and/or simulation support staff (for the purposes of this report we will not be differentiating between planners and planners' assistants as users of the simulation capability). Therefore COA-Sim needs to provide planning functionality that ensures that planners work at an appropriate level of abstraction and are not burdened with tactical or simulation detail, in addition to order and behaviour functionality that minimises the workload of simulation support staff.

Another requirement of COA-Sim is user confidence in the simulation. This is being achieved by working with, and supporting, the ADF training community. This collaboration will strengthen user confidence in COA-Sim and provide a solid foundation for its transition to the operations planning community.

4. The Prototype COA-Sim Environment

4.1 Technical Components

The COA-Sim environment contains a number of technical components, including a graphical user interface (GUI), a suite of sophisticated intelligent software agents that enable automation and behavioural representation (doctrine and standing operating procedures (SOP)) within the simulation environment, and an underlying constructive simulation representing the physical assets. These components exist within a flexible and modular software architecture based on the High Level Architecture (HLA). The COA-Sim environment is being developed using a range of state-of-the-art technologies using expertise that builds on previous experience with other simulation architectures [4] and exposure to other simulation programs.

4.1.1 User Interface

One of the key requirements for the success of COA-Sim is an efficient and effective interface with the operations planning environment – the GUI has a significant role in achieving this. To date GUI development has been undertaken using Java (for ease of development and portability). A number of tailored GUIs has been developed for planning and order & behaviour support for a number of constructive simulations. Ongoing R&D will integrate all COA-Sim GUIs.

4.1.2 Constructive Simulations

A constructive simulation is used to represent physical assets in the air, land and maritime environments (platforms, weapons and sensors). The Joint Theatre Level Simulation (JTLS) [5,6] is the current ADF theatre-level constructive simulation, managed and used by ADFWC. JTLS is used to stimulate headquarters activity for training of the upper operational and strategic level Headquarters staff. In May 2003 the Joint Semi Automated Forces (JSAF) simulation [7] was procured to supplement JTLS by providing the higher entity definition required for most of the Australian operational headquarters which operate at the lower operational and higher tactical level of command (namely Deployable Joint Headquarters (DJFHQ) and Northern Command (NORCOM)). Both JTLS and JSAF form part of the prototype COA-Sim environment.

JTLS and JSAF are both powerful and comprehensive constructive simulations but neither are appropriate to use as a stand-alone operations planning support tool, the key reason being that they require large numbers of staff and long periods of set-up time in order to use. However, this issue will be faced by all simulations unless an efficient and effective interface is developed with the operations planning environment. COA-Sim intelligent agents aim to support the use of constructive simulations such as JSAF and JTLS through reducing simulation operator workload and enabling time frames appropriate for operations planning. These agents will also be applicable to support the use of JTLS and JSAF in training and exercises with the aim of reducing simulation operator workload and enabling the retention of knowledge that is often lost during staff posting cycles. The use of these agents to support JTLS and JSAF in other applications such as experimentation is also relevant.

It is important to stress that JTLS and JSAF are being used to help conduct the COA-Sim R&D program but are not necessarily the most significant simulation tools for operations planning. The key development areas and requirements described in this report hold for an Australian simulation capability as a whole. Many simulations will be needed in a fully integrated 'horses for courses' capability, including simulations of JTLS' and JSAF's nature. In the event that other more appropriate constructive simulations become available then the flexible and modular COA-Sim architecture and agent design will mean that any new simulation could be incorporated with minimum adaptation and redundancy.

4.1.3 Intelligent Agents

COA-Sim requires a suite of sophisticated intelligent software agents that enable automation and behavioural representation within the simulation environment [8,9]. COA-Sim agents must represent or map to behaviour at the operational-level of command. Therefore data is required from appropriate doctrine, SOP and subject matter experts.

Agents in the prototype COA-Sim environment have been developed using the ATTITUDE [10,11] agent programming language. ATTITUDE was developed by DSTO for the development of agents using the beliefs, desires and intentions (BDI) model of intentionality.

4.2 Functional Components

There are two key functional components of COA-Sim: planning support tools (for planners or planners' assistants); and order & behaviour support tools (for simulation operators), see Figure 2.

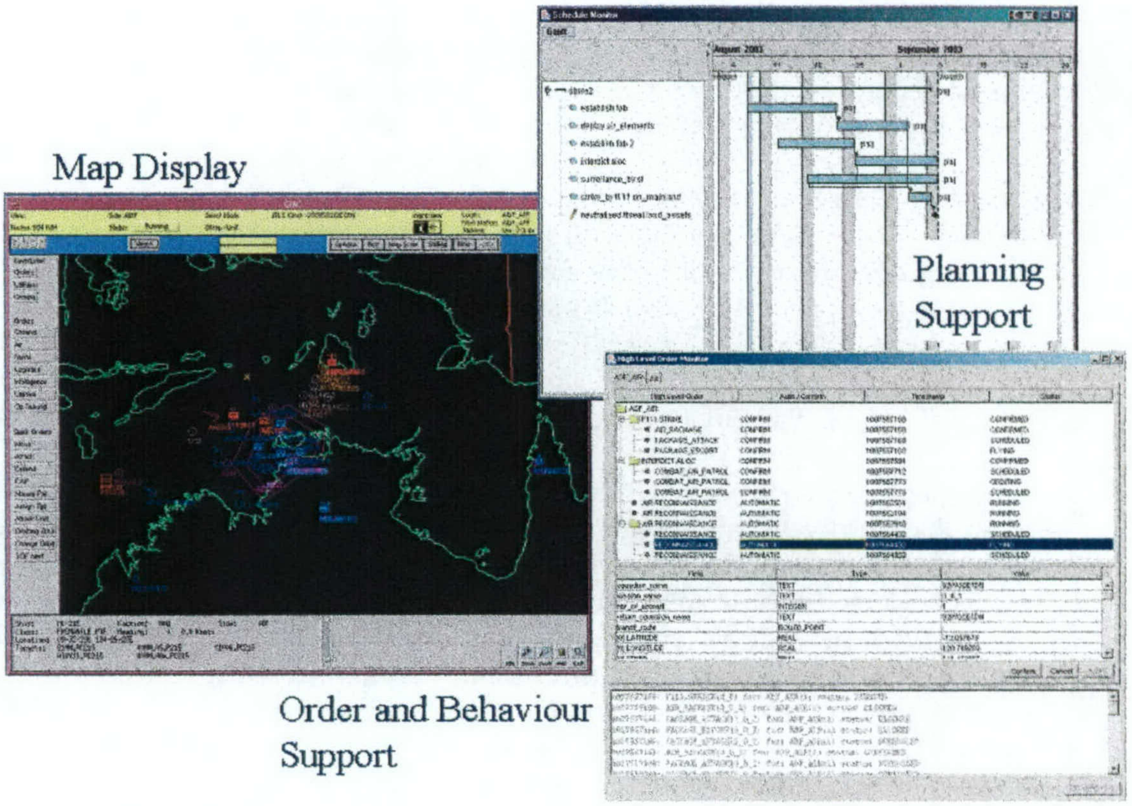

Figure 2. Functional components of the COA-Sim environment (see later for enlarged figures).

Each of these components requires a map of the geo-spatial region and asset locations, necessary due to the temporal and spatial nature of the simulation. The map display used in the prototype COA-Sim environment is provided by the constructive simulation – JTLS is shown in Figure 2 (JSAF has a similar display). This map is suitable for the order and behaviour support tool (used by the simulation operator) but an alternative map may be required for the planning support tool (used by the planners), eg one that can be better integrated with the real operations planning environment. A custom designed map will be considered in future R&D. Note: the order and behaviour support tool can also be used directly in support of training and exercises, in a stand-alone mode.

4.2.1 Planning Support

Planning support tools are designed to ensure that planners work at an appropriate level of abstraction and are not burdened with tactical or simulation detail. A *planning options tool* has been developed as part of an overall planning support tool in COA-Sim. This tool would be used by the planner in the early stages of the COA development phase of the JMAP. The planner would specify a goal condition (or military end state) and the tool would suggest broad options using built-in generic information about military capabilities. The planning options interface allows a planner to select (from a predefined set) a military goal to be achieved through a simple menu system. The goal

is represented by a persistent HLA object in the COA-Sim architecture and communicated to the *planner agent* which constructs a set of possible COA options consisting of operational-level tasks and implied ordering constraints. The HLA object is then updated and the results are conveyed back to the planning options interface that displays each COA as a separate Gantt chart.

Figure 3 shows the planning options generated to achieve the end-state *Neutralised Threat Land Asset*, showing the range of options that can be presented to achieve a single task. The automated reasoning undertaken by the planner agent has not considered any resourcing issues, rules of engagement or the nature of the target to be attacked but will help identify infeasible options and focus on those that are most promising (resource and other issues associated with COA generation are the subject of C2D's COA scheduling R&D program with which the COA-Sim R&D is being integrated [12]).

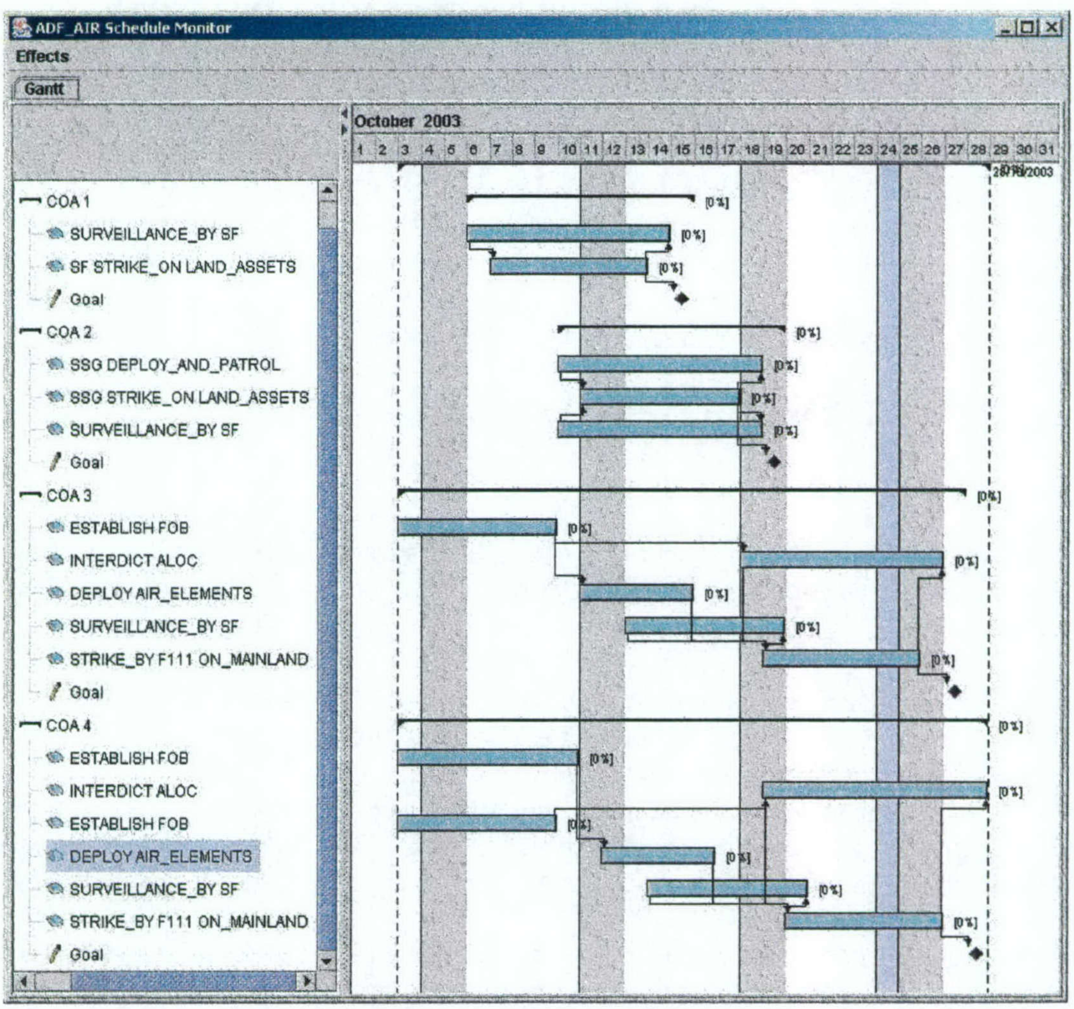

Figure 3. The planning options mode as part of the COA-Sim planning support tool. Planning Options for the end-state, Neutralised Threat Land Asset. *Note four qualitatively different approaches of increasing complexity. Task durations are not scaled realistically.*

The current prototype of the planning options tool allows the planner to adjust the timing of tasks within each COA, subject to existing constraints, and add new ordering constraints. Ongoing work will enable the user to remove COAs, and add additional conditions to be achieved, initiating further automatic planning and generating a new set of options. Future work, as part of broader COA generation R&D, will consider resource usage, allow constraints to include absolute and relative times, and give a user the ability to interrogate the displayed COA to find what conditions relate to particular ordering constraints, as well as the ability to create more complex goals and specify the initial starting state.

4.2.2 Order and Behaviour Support

Order and behaviour support tools are designed to assist with the execution of the constructive simulation in the interest of timeliness and minimising simulation support staff workload. Order and behaviour support within COA-Sim is therefore strongly linked to the underlying constructive simulation.

A selection of operational-level orders have been integrated into JTLS and JSAF (described further in the following sections, specific to each constructive simulation). These orders translate operational-level tasks into manageable simulation-level behaviours within JTLS/JSAF (and thus helps to minimise the workload of simulation support staff) which otherwise would require input of many individual JTLS/JSAF orders and significant human reasoning of the task requirements.

4.3 The JTLS-based COA-Sim Environment

4.3.1 Order and Behaviour Support

A selection of operational-level orders have been integrated into JTLS to provide order and behaviour support to the JTLS simulation operator (or response cell, in JTLS terminology).

The JTLS GIAC can be tailored to include additional orders that are accessed via order *buttons* and pull down menus. These orders initiate pop-up windows where information and parameters concerning the order may be entered. The JTLS-based COA-Sim environment currently provides three operational-level orders in an "Op Planning" menu, namely "Interdict ALOC" (air lines of communication (ALOC)), "F111 Strike", and "Air Reconnaissance".

In Figure 4 the "Interdict ALOC" order is selected within the "Op Tasking" menu. This order allows a planner to create an air interdiction task that schedules continuous patrols of fighter aircraft at a specified location, which may be a moving location such as above a ship. Within a new window the user specifies mission name, the number of aircraft on CAP at any one time, any tanker or airborne early warning (AEW) support

available, an arrival time at the CAP location (nul, now, ASAP, or specific time), the duration of the CAP, agent behaviour (automatic or requiring confirmation), the interdiction area options (location/radius, unit/radius, operational area or formation), the location of the CAP (either a lat/long can be entered or a location can be selected on the GIAC map display), and the radius of the CAP (note: nul is typically only used for testing purposes). Buttons at the bottom of the window allow the user to *send* the order, set the current values as the *default*, *save* the current order to be sent later or as a template, *clear* the order, get some *help* or *close* the order window. Once the order is sent a scheduling algorithm is used within the Interdict ALOC component of the *executor agent* that determines the aircraft availability for the period of interest and commences to allocate aircraft to missions to fill the required schedule (note: the Interdict ALOC component of the executor agent is also referred to as the CAP agent later in this report). The resulting allocations are shown in the order and behaviour support GUI and as they are executed the desired behaviour is reflected in the GIAC. The implementation does not currently account for tanker or AEW support, and does not adequately support a moving location.

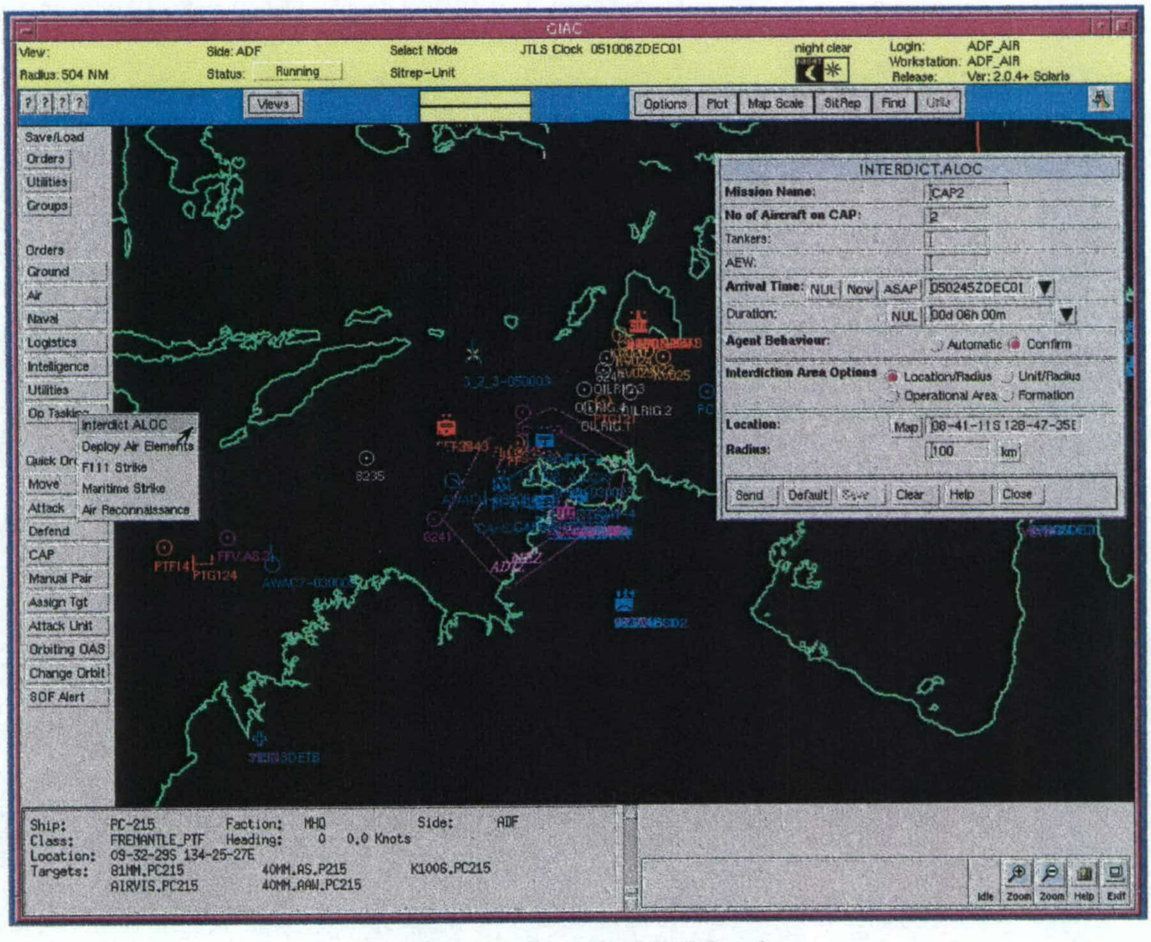

Figure 4. The Interdict ALOC order.

In Figure 5 the "F111 Strike" order is selected within the "Op Planning" menu. This order enables a planner to create an air-to-surface strike task. A new F111 Strike window appears where the user can select mission name, target list, number of tankers, strike time (nul, now, ASAP, or specific time), agent behaviour (automatic or confirm), and strike strength (desired force ratio or aircraft number). If aircraft number is selected in the strike strength field, then the number of strike, escort, suppression of enemy air defence (SEAD) and battle damage assessment (BDA) must be input, otherwise the user can specify the proportion of the force that should be assigned to each of these mission components, with the size of the force determined from the expected strength of response and a desired force ratio. Buttons at the bottom of the window allow the user to *send* the order, set the current values as the *default*, *save* the current order to be sent later or as a template, *clear* the order, get some *help* or *close* the order window. Once the order is sent the F111 Strike component of the *executor agent* determines the aircraft availability for each of the mission components and creates an appropriate mission package. The resulting sub-tasks are shown in the order and behaviour support GUI and when the orders are executed the movement of the strike package can be seen in the GIAC. The current implementation does not account for force ratio in the strike strength field.

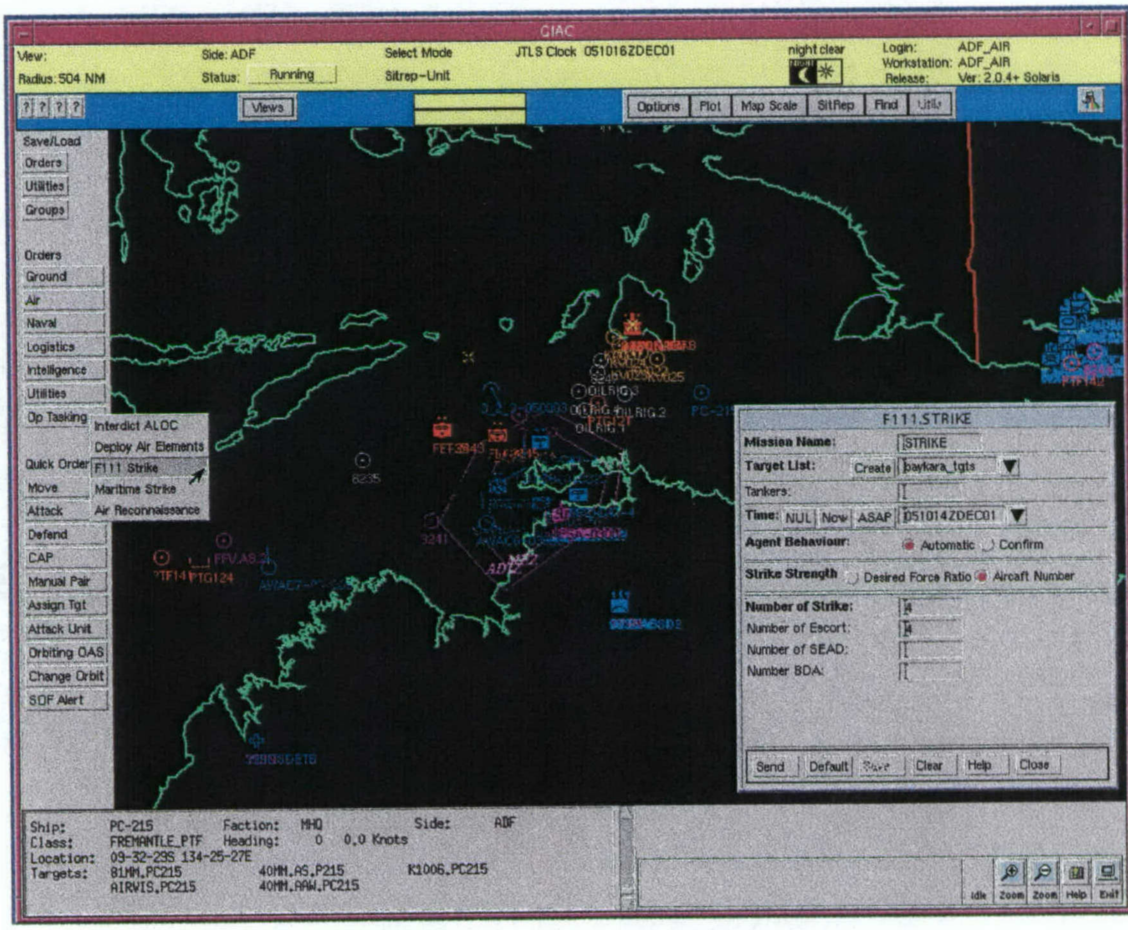

Figure 5. The F111 Strike order.

In Figure 6 the "Air Reconnaissance" order is selected within the "Op Planning" menu. This order allows the planner to create an air reconnaissance task that schedules reconnaissance aircraft to patrol a wide area over an extended period. A new Air Reconnaissance window appears where the user can select mission name, the total number of allocated aircraft for the task, mission start time (nul, now, ASAP, or specific time), mission duration, agent behaviour (automatic or confirm), patrol area type (predefined OPAREA or Polygonal area). If Polygonal area is selected then the user can go to the GIAC map display and draw the polygon for this mission. Buttons at the bottom of the window allow the user to *send* the order, set the current values as the *default*, *save* the current order to be sent later or as a template, *clear* the order, get some *help* or *close* the order window. Once the order is sent the Air Reconnaissance component of the *executor agent* calculates a search path and the scheduling algorithm determines aircraft availability and allocates aircraft to missions to fill the required schedule. The resulting low-level orders are shown in the order and behaviour support GUI and as they are executed the desired behaviour is reflected in GIAC. The current implementation does not divide up large search areas for search by multiple aircraft or allow more than one aircraft to be searching at a time.

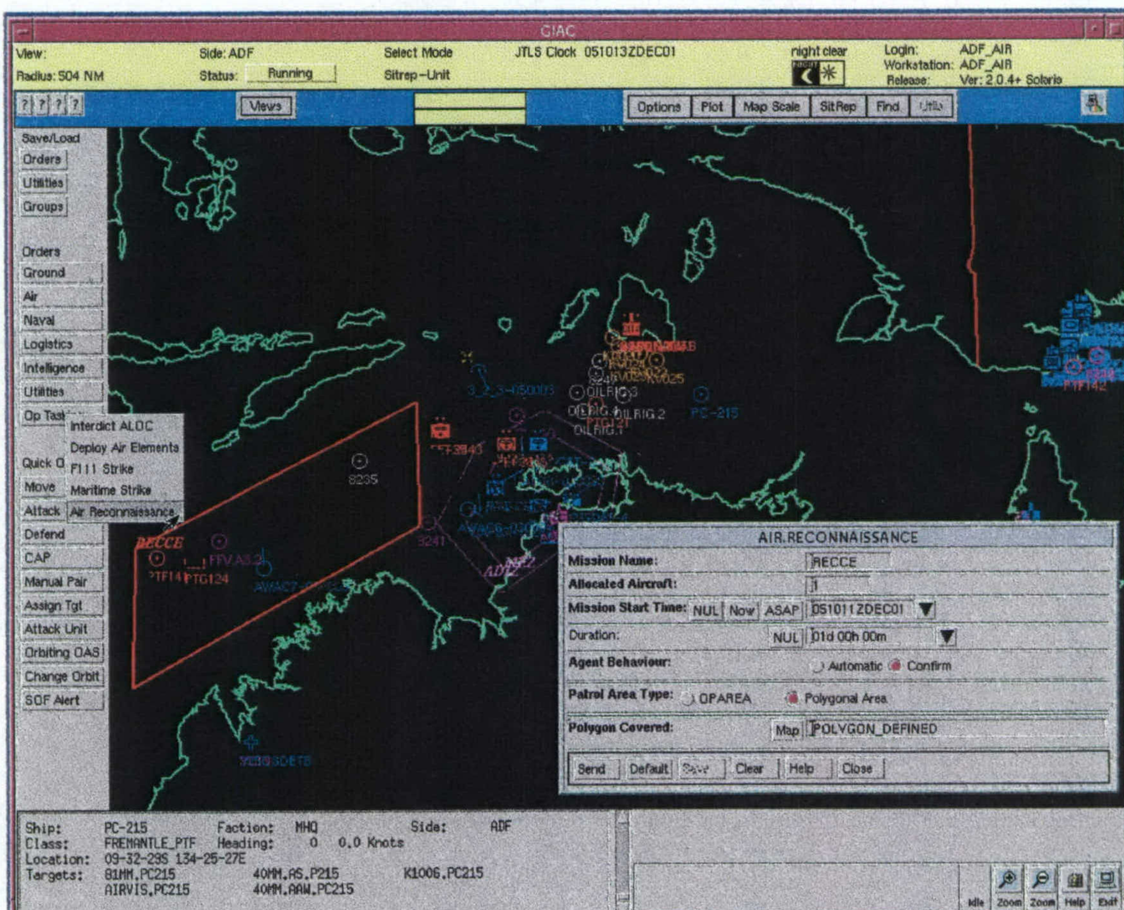

Figure 6. The Air Reconnaissance order.

In addition to the provision of operational-level orders within JTLS, a number of other order and behaviour support features have been developed in support of the simulation operator. These features relate to the operational-level orders and provide the following information within a GUI (see Figure 7): the operational-level task and decomposition to sub-tasks; automatic or confirm status (if confirm was selected then user confirmation of the task decomposition is required before undertaking the simulation); the timestamp associated with each task (for timing and sequencing of subtasks); and simulation status (eg aircraft flying, refuelling, returning to base; or agent awaiting confirmation).

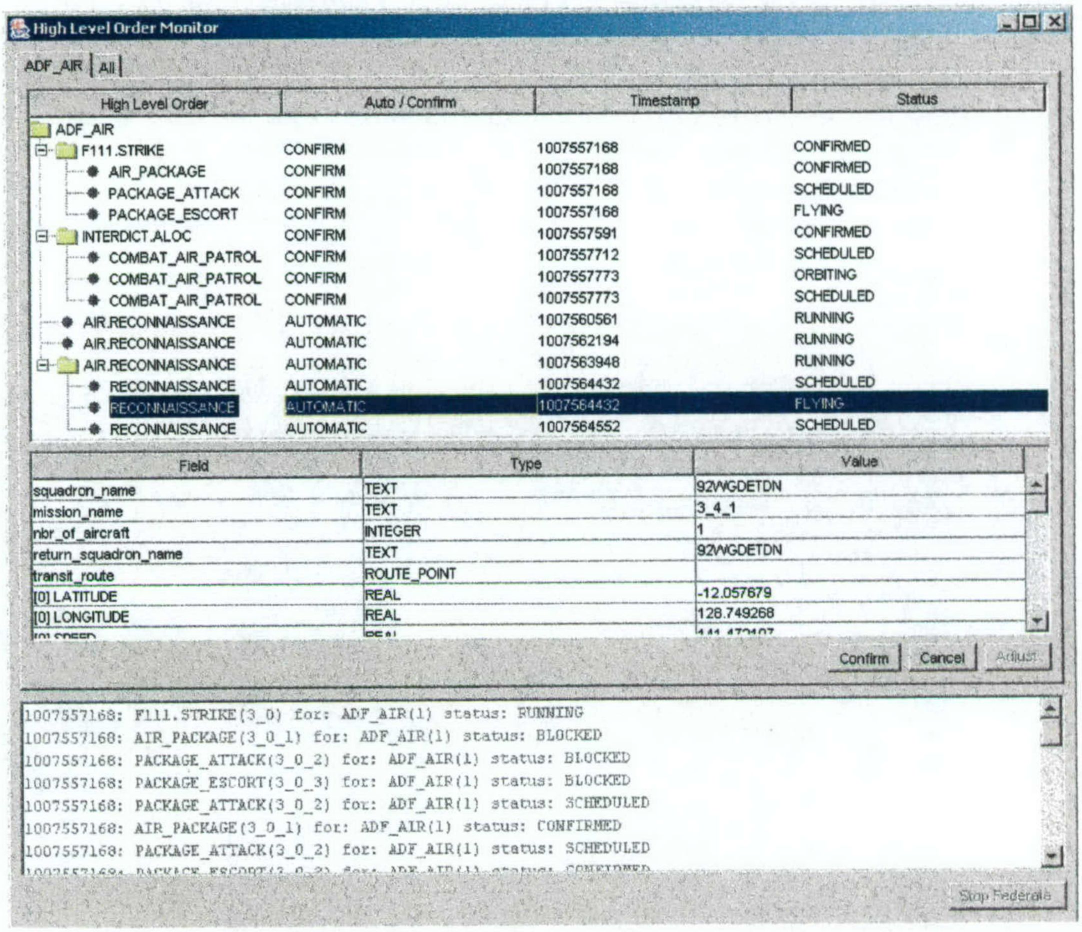

Figure 7. The COA-Sim order and behaviour support GUI.

The order and behaviour support GUI consists of a Windows™ Explorer-style browser in the top window pane that allows the user to easily see the hierarchical contents of each task, and also quickly see the automation status and the simulation status of the order. In the centre pane the user can examine the detailed field values of the order selected in the top pane, either before or after the order is sent to the simulation. Some of this information may be currently obtainable from JTLS but takes considerable time

to find in an assortment of files and locations. The user also has the option to confirm or cancel orders if required, either individually or all at once (by selecting the parent order).

4.4 The JSAF-based COA-Sim Environment

4.4.1 Order and Behaviour Support

JSAF has also been integrated into the COA-Sim environment with an aim to provide the same order and behaviour support functionality available for JTLS. This required modification of the underlying agent behaviour and developing new interfaces with the constructive simulation.

There were a number of significant issues regarding this integration, particularly with regards to the intelligent agents. JSAF is a tactical-level simulation, compared with JTLS which is an operational-level simulation, therefore additional behaviour needed to be integrated into the agents in order to support JSAF. Simulation data and information is also stored and accessed differently for JTLS and JSAF, so this needed to be accounted for in the agents. JSAF does not allow external creation and control of entities (this is necessary for agents to control entity behaviour) so considerable effort was required to enable this (entities can be created and controlled externally in JTLS using HLA). Some JSAF data/information is available through HLA, but considerable effort was required to extract additional information from JSAF (via changes to the source code) for use by the agents. Significant modification to agent behaviour was also necessary in some cases (due to unavailable data). This resulted in reduced agent functionality compared to that available within JTLS.

Despite these difficulties, an "Interdict ALOC", or "CAP", operational-level order has been integrated into JSAF. This CAP order enables a simulation response cell to specify a task to maintain CAP at a given location using available assets from nearby bases. This required the modification and extension of the JTLS-based CAP agent, incorporation of an additional order menu and editor in the JSAF GUI (see Figure 8) through modification of source code, and integration of the ATTITUDE intelligent agent software with JSAF via HLA.

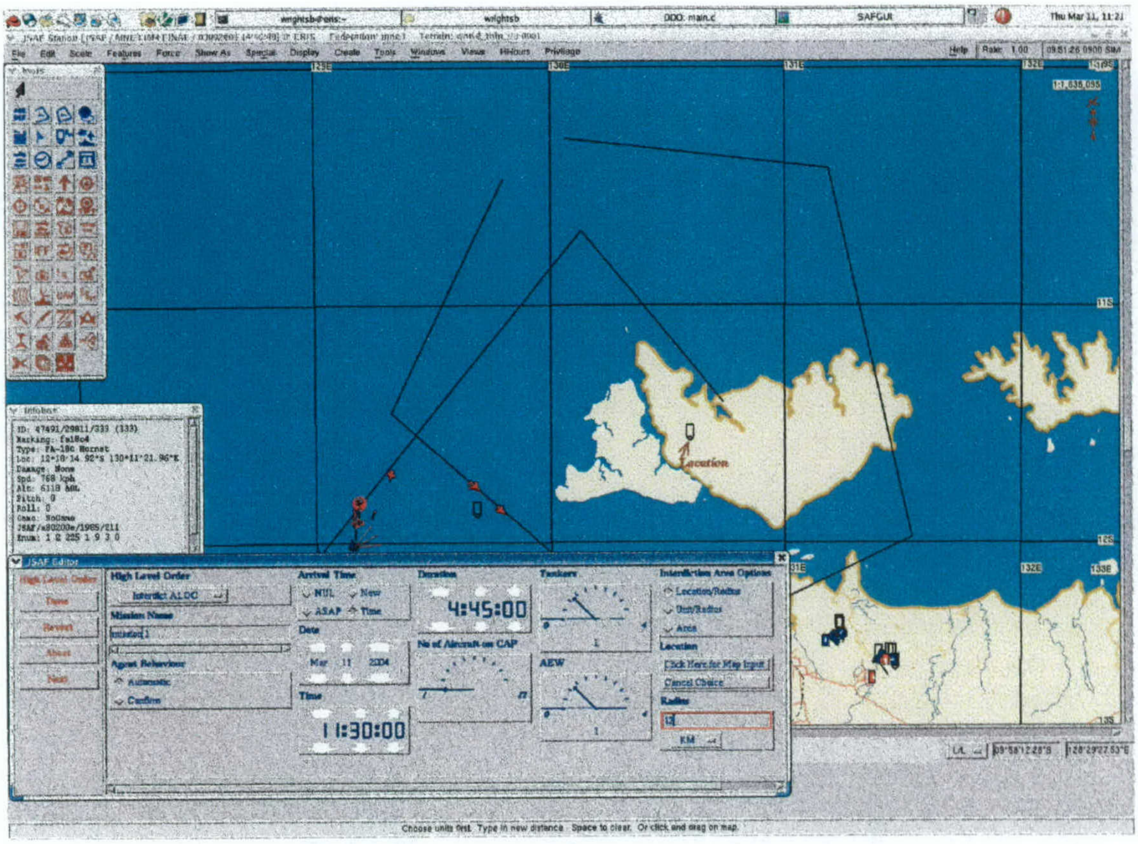

Figure 8. The JSAF GUI containing the COA-Sim high-level order menu and editor.

The CAP agent developed for JTLS was modified for use by JSAF for a number of reasons. JSAF tracks aircraft individually and has no knowledge of squadrons or 'home' bases (JTLS did have this knowledge). But scheduling is more efficient (faster to derive a schedule which requires less ongoing maintenance) if it is done on the basis of squadrons — for these purposes defined as groups of aircraft of the same type that are based at the same location, any of which can be used for a particular mission. The set of available resources is retrieved from the JSAF run-time database (maintained via a third party product hlaResults [13]) and this is sorted into squadrons (based on a naming convention in this case, but it could be on any well-defined basis). The set of resources is used by the scheduler to determine a schedule of missions to satisfy the CAP requirement, where each mission obligates a number of aircraft from a particular squadron to fill a slot in the CAP schedule. These missions are then allocated to individual aircraft in JSAF, aircraft which take off to fly the required missions and return back to their, externally defined, 'home base'. There are some limitations with the use of the current JSAF CAP agent that will be addressed in the ongoing R&D program. Many of the limitations are due to the difficult access and limited availability of information within JSAF.

Further investigation regarding the retrieval of tasking information from JSAF (in the form of HLA interactions) has also begun. This supports a range of potential new

behaviours by allowing external agents to determine what tasks entities are currently doing, what they are going to do, and when they are going to do it. This information can, for instance, be used to develop a more accurate schedule for the CAP behaviour described above which presently assumes any aircraft that is currently at base is available, and any aircraft that is not currently available will become available when it has consumed its current fuel allocation (a fuel allocation which is assumed to be maximum). Neither of these assumptions are reliable so the resultant schedules are not very robust. The ability to determine actual asset availability will be rolled into the JSAF CAP agent at a later date.

4.4.2 Analysis – Operational-level Reports of Simulation Outcomes

Significant outcomes from simulations are typically related to the number of assets lost on each side, but determining the significance of such losses is complicated, particularly while the simulation is running. When an asset is destroyed or damaged the overall capability of a force is reduced by some amount. The significance of any single such event, or ongoing attrition, is difficult to objectively determine because each asset can contribute to many separate capabilities. The *simulation results analysis agent* attempts to address this problem by providing a way to characterise the military capabilities of a force, and parts of the force, and thus to objectively estimate the significance of losing part of this force in terms of its effect on capability.

A simple tool has been developed to analyse and display the military capabilities of a force. The current implementation of the tool undertakes analysis that characterises the military capabilities of a force in terms of its ability to attack. This capability is more precisely characterised by the physical operating environment of the respective targets. In other words, by the separate capabilities to attack air, land, water surface and subsurface targets. Future work will extend the analysis to include the ability of a force to detect, communicate, move and transport.

The military capabilities are determined by automated analysis of a combination of static simulation data files and the dynamic simulation database within the constructive simulation (JSAF in this case). This allows an assessment of overall capabilities to engage targets in particular environments by looking at the number and characteristics of the assets and their munitions over some aggregation of units.

The capability measured in this way then becomes a baseline against which changes in capability can be compared to give a percentage change from its nominal or starting strength. The capability is considered loosely to be composed of a *length* and *strength*, and they characterise the capability in different ways. A strong capability is one that can deliver a high peak capability, while one with length can deliver a sustained capability. In the case of an attack capability the *strength* is the number of weapon delivery channels (eg number of guns or weapon launch systems on a ship) while the *length* is the amount of ammunition (eg missiles) available per weapon delivery channel. Thus *length* x *strength = total amount of ammunition available.*

Figure 9 shows the results from the initial capability analysis for a Blue force designed to enforce a maritime exclusion zone (MEZ). This group contained 3x ANZAC class frigates and one Destroyer, a logistic support vessel (Success) and a Collins class submarine, with 12x F/A-18 on standby nearby (four in a strike role) and a single ground-based air defence (GBAD) unit based on an island. Each column shows the aggregated capability of the elements in the group to attack targets in a particular environment, subdivided vertically into contributions from assets that operate in particular environments. The GBAD unit, as the only land unit in the group, appears as the entry 4.0 x 6.0 (*length* x *strength*) in the Air column – meaning that there are six surface-to-air missile launchers and each launcher has four missiles to fire. The specific values for the entry are obtained from a combination of the JSAF static simulation data files (platform/asset capabilities) and the run-time simulation database (actual numbers of platforms/assets available). The interface also displays row and column totals, and a percentage that shows the current capability as a fraction of its starting state.

Capability Tool

	Ground	Underground	Air	Water	Space	Underwater		Total	% of Initial
vehicleEnvironmentAir	4.3 x 72.0	0.0 x 0.0	6.0 x 12.0	4.0 x 30.0	0.0 x 0.0	0.0 x 0.0		504	100
vehicleEnvironmentGround	0.0 x 0.0	0.0 x 0.0	4.0 x 6.0	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0		24	100
vehicleEnvironmentWater	106.9 x 17.0	0.0 x 0.0	16.2 x 13.0	87.5 x 21.0	0.0 x 0.0	0.0 x 0.0		3865	100
vehicleEnvironmentSpace	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0		0	100
Total	2129	0	307	1957	0	0			
% of Initial	100	100	100	100	100	100			

Figure 9. Initial Blue force capability analysis of "enforce a MEZ". Each cell shows the Blue force capability (length×strength) to engage Red targets operating in a particular physical environment (column) using Blue assets that operate in another, possibly different, physical environment (row). Column totals give a measure of the overall capability to engage targets in the given environment, and the percentage shows how much this has changed from the starting state.

Figure 10 shows the dynamic effect on the Blue force capability after a Red air strike in which part of the Blue GBAD capability and one of the Blue frigates was destroyed. This shows that the effect of this attrition has been to reduce the capability of the Blue force to attack targets in the air and water surface domains by about 20%.

Capability Tool

	Ground	Underground	Air	Water	Space	Underwater		Total	% of Initial
vehicleEnvironmentAir	4.3 x 72.0	0.0 x 0.0	6.0 x 12.0	4.0 x 30.0	0.0 x 0.0	0.0 x 0.0		504	100
vehicleEnvironmentGround	0.0 x 0.0	0.0 x 0.0	4.0 x 5.0	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0		20	83
vehicleEnvironmentWater	99.5 x 14.0	0.0 x 0.0	15.0 x 11.0	78.5 x 18.0	0.0 x 0.0	0.0 x 0.0		2971	76
vehicleEnvironmentSpace	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0	0.0 x 0.0		0	100
Total	1705	0	257	1533	0	0			
% of Initial	80	100	84	78	100	100			

Figure 10. Blue force capability analysis of "enforce a MEZ", after a Red air strike that damaged GBAD and water surface assets.

A prototype capability analysis tool is currently available which demonstrates the concepts. Ongoing development is still required due to the unavailability of dynamic JSAF run-time data regarding platform/asset payload (only static data is available) and partial damage (reporting is only available if an entity is destroyed). Ongoing development will also augment the tabular view of results with various graphical views for easier interpretation.

5. Future R&D

A number of extensions and improvements to various agents and interfaces have already been suggested throughout the report. Achievement of these extensions will be undertaken as part of an on-going COA-Sim R&D program.

The next significant R&D component is development and integration of three modes of COA-Sim [8], namely

- planning options,
- feasibility assessment, and
- analysis.

Prototype planning options and analysis tools have already been developed, but these are essentially standalone in operation. A key requirement for the success of the use of the three modes of the COA-Sim environment is their integration to provide an incremental approach (in conjunction with incremental data input) to develop, refine and analyse a COA. This requires significant integration between each mode and a single information database/repository.

6. Issues and Challenges

There are many behavioural representation and other challenges facing the efficient and effective use of simulation in operations planning. One of the issues relates to the data and models underpinning the entity and behaviour representation. Not only must this data and models be verified and validated but also must be maintained and supported throughout the life of the simulation.

A constructive simulation (JTLS or JSAF in this case) provides the entity representation within the COA-Sim environment. Therefore the verification, validation and accreditation (VV&A) and ongoing maintenance and support of data within the constructive simulation is necessary for the success of COA-Sim (and any simulation capability for that matter). Much of this data is common to many simulations as well as in-service command support systems so data management and its resourcing, as well as associated interoperation of simulation and real systems, should not be matters that are left in the hands of any single interested party. Rather these matters need to managed or at least coordinated by a central body with an interest that crosses those of all the stakeholders.

Data availability and VV&A are also key issues for intelligent agent development and are important to strengthen user confidence. Appropriate operational-level doctrine, SOP and subject matter experts are referenced, where possible, throughout COA-Sim agent development. Continued maintenance and support of agent behaviour is also necessary to ensure longevity. This requires agents to be easily (or even automatically) updated with changing doctrine and SOP. To date, agent development has involved the "hard-coding" of doctrinal and SOP information. Intelligent agents take considerable time to develop (months) and have large data management overheads. Future work must explore the ability to develop agents much faster and have the ability to automate data and behaviour input. This may necessitate a requirement for electronic doctrine and SOP which could be automatically translated into simulations.

7. Summary

COA-Sim aims to provide a systematic component to the COA development and analysis phases of operations planning. This will result in an increased confidence in the COA and a better knowledge of unexpected possible outcomes, resulting in a more refined and well-founded plan.

An exploration of the use and applicability of simulation in support of planning has been undertaken with the concepts being successfully developed and demonstrated in a prototype COA-Sim environment. Significant progress has been made on a number of tools within the environment. These tools will assist planners in the construction, modification and analysis of a course of action described by a set of operational-level tasks.

A planning options tool is available where a planner would specify a goal condition (or military end state) and the tool would suggest broad options using built-in generic information about military capabilities. A selection of operational-level orders (CAP, strike, and air reconnaissance) have been integrated into JTLS to provide order and behaviour support to the JTLS operator. A JTLS-based order and behaviour tool allows the user to easily see the hierarchical contents of each operational-level task, the detailed field values of a sub-task, and also quickly see the automation status and the simulation status of the order. A CAP operational-level order has been integrated into JSAF to provide order and behaviour support to the JSAF operator - the same functionality that is available in JTLS. A simple JSAF-based analysis tool has been developed to analyse and display military capabilities of a force. The current implementation of the tool undertakes analysis that characterises the military capabilities of a force in terms of its ability to attack.

Further funding would allow R&D into the extension and integration of the standalone tools to provide unified planning options, feasibility assessment and analysis modes within the COA-Sim environment.

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19. ABSTRACT

This document provides a report for the Australian Defence Simulation Office (ADSO) on COA-Sim R&D undertaken with the support of ADSO minors funds in the 03/04 financial year. The R&D focussed on developing a prototype Course of Action Simulation capability. Course Of Action Simulation (COA-Sim) is an R&D program aimed at exploring the applicability of simulation to operations planning support. COA-Sim aims to provide a systematic component to the COA development and analysis phases of operations planning. This will result in an increased confidence in the COA and a better knowledge of unexpected possible outcomes, resulting in a more refined and well-founded plan. An exploration of the use and applicability of simulation in support of planning has been undertaken with the concepts being successfully demonstrated in a prototype COA-Sim environment.

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